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SPECIFICATION FOR INDUSTRIAL PROCESS CONTROL VALVES

PART I GENERAL REQUIREMENTS AND TESTS

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Indian Standard

SPECIFICATION FOR INDUSTRIAL PROCESS CONTROL VALVES

PART I GENERAL REQUIREMENTS AND TESTS

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Indian Standard

SPECIFICATION FOR INDUSTRIAL PROCESS CONTROL VALVES

PART I GENERAL REQUIREMENTS AND TESTS

0. FOREWORD

0.1 This Indian Standard (Part I) was adopted by the Indian Standards Institution on 12 May 1982, after the draft finalized by the Industrial Process Measurement and Control Sectional Committee had been approved by the Electrotechnical Division Council.

0.2 This standard has been prepared with a view to specify an acceptable performance level of control valves in terms of flow co-efficient, inherent flow characteristics and seat leakage rate. The test methods have also been specified.

0.3 The control valve sizing under installed conditions is covered under Part II of this standard.

0.4 In preparing this standard considerable assistance has been derived from IEC Pub 534-1 (1976) ' Industrial process control valves : Part 1 General considerations ' issued by International Electrotechnical Commission.

0.5 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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1. SCOPE

1.1 This standard (Part I) covers the basic definitions, tolerances on flow coefficients, classification and methods of tests for all types of industrial process control valves.

*Rules for rounding off numerical values (*revised*).

2. TERMINOLOGY

2.0 For the purpose of this standard, the following definitions shall apply.

2.1 Control Valve — A power-operated device forming a final element in an industrial process control system. It consists of a body subassembly containing internal means for changing the flow rate of the process fluid. The body subassembly is linked to one or more actuators which respond to a signal transmitted from controlling element.

2.2 Travel — The displacement, from the closed position, of the internal means for changing the flow rate of the process fluid.

2.2.1 *Rated Travel*— The travel from full closed position to full open position and back.

2.2.2 *Relative Travel* (h) — The ratio of the travel at a given opening to the rated travel.

2.3 Flow Coefficient — A term used to state flow capacity at a given travel under specified conditions. Theoretically, it is defined by the following equation:

$$A_v = Q\sqrt{\frac{\rho}{\Delta P}}$$

where

A_v = flow coefficient in square metres;

Q = flow rate in cubic metres per second;

ΔP = pressure differential across the control valve in pascals; and

ρ = density of a Newtonian liquid flowing through the control valve in kilograms per cubic metre.

When ΔP is measured in bar (*see* Note 2), then:

$$A_v = Q\sqrt{\frac{\rho}{\Delta P \times 10^5}}$$

In practice, the following equation is commonly used:

If K_v is the number of cubic metres per hour of water at a temperature between 5°C and 40°C that will flow through a control valve with a one-bar pressure differential at a specified travel, then:

$$K_v = \frac{A_v \times 10^6}{28}$$

Note 1 — A_v is not the area of the control valve orifice since it includes the effects of contraction and hydraulic resistance of the fluid (*see* Appendix A).

Note 2 — 1 bar = 10^5 P_a.

2.3.1 *Rated Flow Coefficient* — The value of the flow coefficient at rated travel.

2.3.2 *Relative Flow Coefficient* (ϕ) — The ratio of the flow coefficient to the rated flow coefficient.

Mathematically, ϕ may be defined as follows:

$$\phi = \frac{\text{flow coefficient at } h}{\text{rated flow coefficient}}$$

where

h = relative travel.

2.4 Control Valve Seat — The surface of a control valve orifice or a control valve body subassembly interior which makes contact with movable internal means, such as a plug, ball or vane, when the control valve is closed.

NOTE — A common flow passage may be located between two separate control valve seats (double-seat) for purpose of static plug balance.

2.5 Control Valve Port — The passageway, between the upstream and downstream cavities of the control valve body subassembly providing a throttling flow passage between them.

NOTE — Certain globe-type control valves employ two ports in parallel (double-port) for purposes of static plug balance.

2.6 Inherent Flow Characteristic — The relationship between the relative flow coefficient and the corresponding relative travel.

2.6.1 *Linear Flow Characteristic* — An inherent flow characteristic for which, theoretically, equal increments of relative travel yield equal increments of relative flow coefficient (*see* Fig. 1).

Mathematically: $\phi = \phi_0 + \text{mh}$

where

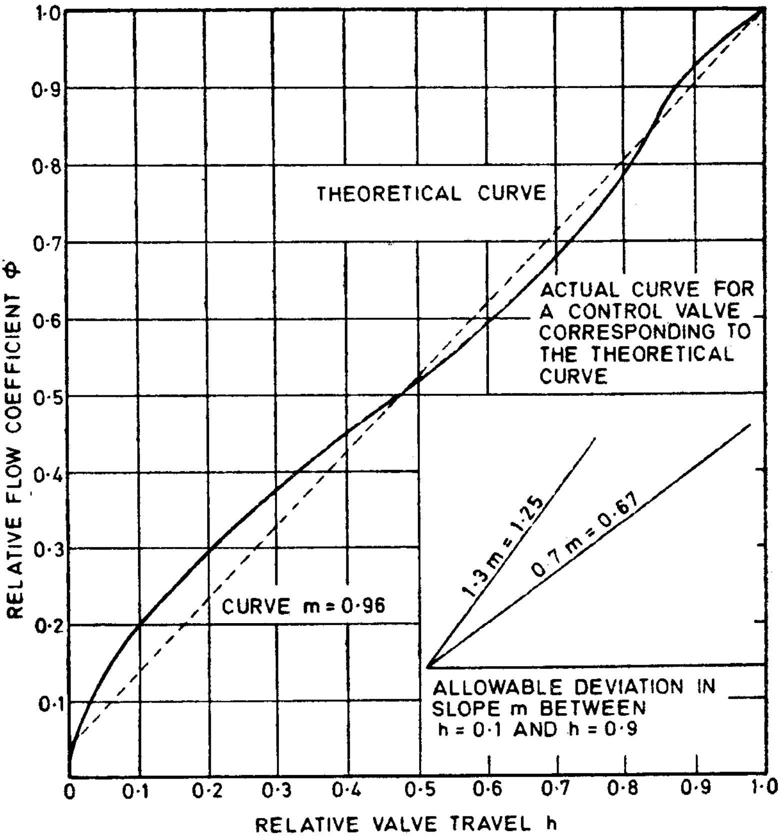
ϕ_0 = relative flow coefficient corresponding to $h = 0$,

m = slope of inherent linear flow characteristic, that is, the ratio of increment of relative flow coefficient to unit increment of relative travel, and

h = relative travel.

when : $h = 1, \phi = 1$,

hence: $m = 1 - \phi_0$.



NOTE — For actual tests, the value of rated flow coefficient at $h = 1$ may vary by $\pm$ 10 percent from theoretical value (*see* **4.1**).

FIG. 1 LINEAR INHERENT FLOW CHARACTERISTIC

2.6.2 *Equal Percentage Flow Characteristic* — An inherent flow characteristic for which theoretically equal increments of relative travel yield equal percentage changes of the relative flow coefficient (*see* Fig. 2).

Mathematically: $\phi = \phi_0 e^{nh}$

where

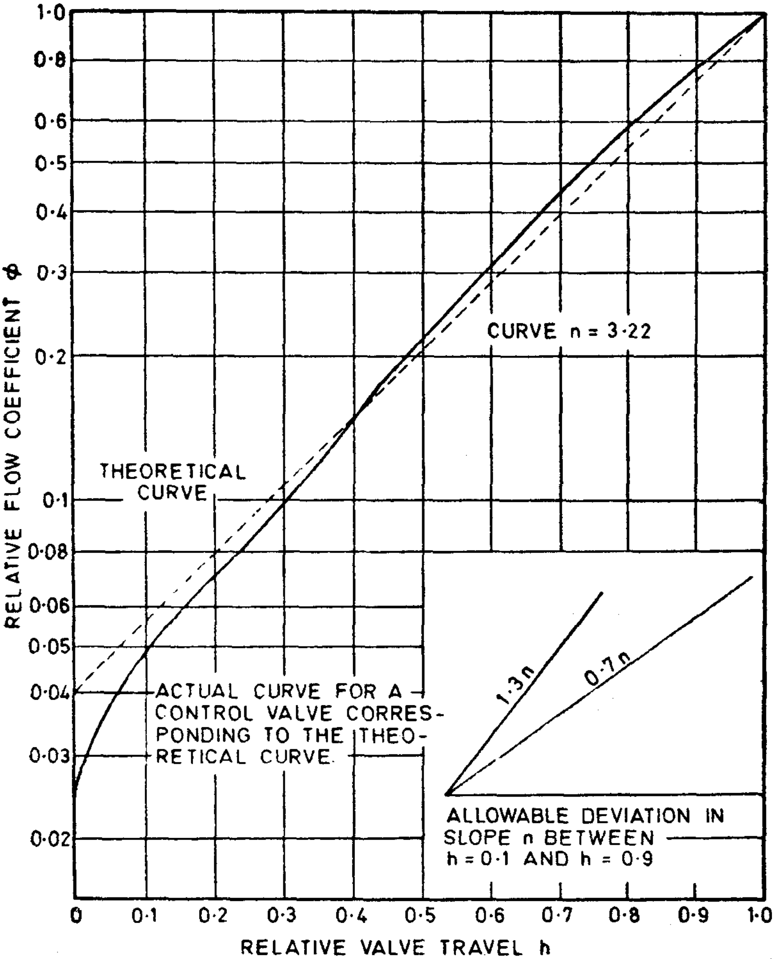
ϕ_0 = relative flow coefficient corresponding to $h = 0$,

n = slope of the inherent equal percentage flow characteristic when $\log_e \phi$ is plotted against h, and

h = relative travel.

When : $h = 1, \phi = 1$.

hence : $n = \log_e \left(\dfrac{1}{\phi_0} \right)$



NOTE — For actual tests the value of rated flow coefficient at $h = 1$ may vary by $\pm$ 10 percent from theoretical value (*see* **4.1**).

FIG. 2 EQUAL PERCENTAGE INHERENT FLOW CHARACTERISTIC

2.7 Inherent Rangeability — The ratio of maximum to minimum controllable flow coefficient. The flow coefficient is regarded as controllable only within the range of relative travel for which the slope of the inherent flow characteristic does not deviate from stated limits.

2.8 Trim — The internal parts of a valve body assembly which come in contact with the controlled fluid.

3. CLASSIFICATION

3.1 Control valves shall be classified according to the following considerasions:

3.1.1 *Design*

3.1.1.1 *Body type*

a) Globe,

b) Angle,

c) Ball,

d) Butterfly,

e) Diaphragm,

f) Split body,

g) Bottom flange, and

h) Other.

3.1.1.2 *Number of ways*

a) Two-way,

b) Three-way, and

c) Four-way.

3.1.1.3 *Number of ports*

a) Single,

b) Double, and

c) Multiple (cage type).

3.1.1.4 *Number of seats*

a) Single, and

b) Double.

3.1.1.5 *Guides*

a) Top,

b) Bottom, and

c) Top and bottom.

3.1.1.6 *Body end connections*

a) Flanged,

b) Flangeless (suitable for clamping),

c) Threaded,

d) Welding, and

e) Other.

3.1.2 *Operating Power*

a) Pneumatic,

b) Hydraulic,

c) Electric, and

d) Any combination of the above.

3.1.3 *Operating Direction*

a) Control valve closes with increasing input signal, and

b) Control valve opens with increasing input signal.

3.1.4 *Action on Failure of Operating Power*

a) Control valve closes,

b) Control valve opens, and

c) Control valve maintains the last throtting position.

3.1.5 *Inherent Flow Characteristic*

a) Linear,

b) Equal percentage,

c) Quick opening,

d) Parabolic,

e) Modified parabolic, and

f) Other.

4. GENERAL REQUIREMENTS

4.1 Rated Flow Coefficient — A flow coefficient calculated from the results of a test on an individual control valve, as specified in **6.7** shall not deviate from the value specified as being typical for the control valve under test by more than ± 10 percent at maximum relative travel.

4.2 Inherent Flow Characteristic — The slope *m* or *n* of the actual inherent flow characteristic, when calculated from the results of a test on a typical control valve, as specified in **6.8** shall not deviate from the slope of the specified theoretical characteristic for the control valve under test by more than ± 30 percent for all values of relative travel between 0·1 and 0·9 (*see* Fig. 1 and 2).

4.3 Seat Leakage — Seat leakage rates for control valves shall not exceed the following values, expressed as a percentage of rated valve capacity:

Seat Leakage Rates for Metal to Metal Seating

	Single Port	*Double Port*
Single seat	0·05%	Not applicable
Double seat	0·5%	0·5% (Class 1) 0·1% (Class 2)

For above valves with soft seating or any special treatment and for other types of control valves, the seat leakage rate shall be specified by the manufacturer.

When seat leakage rates are calculated, test conditions shall be assumed and the appropriate equations and the rated flow coefficient shall be utilized (*see* Fig. 1 and 2).

5. MARKING

5.1 The nameplate of a control valve shall be marked with the following information and shall be fixed on the actuator:

a) Nominal size: represented by the letters DN followed by a number which is the size in millimetres;

b) Pressure rating: represented by the letters PN followed by a number which is pressure in bar at 20°C;

c) Body material designation and trim material;

d) Manufacturer's name or trade-mark and serial number;

e) Rated flow coefficient (A_V or K_V; to be stated);

f) Inherent flow characteristic (linear, equal percentage or other to be stated);

g) Tag number;

h) Class of valve (double port double seat only);

j) Type or plug (fluted, V port, parabolic, etc); and

k) Caption of statutory approval (for example, ' IBR approved ').

5.1.1 The body of the control valve shall be marked with the following information by casting or punching:

a) Manufacturer's serial number,

b) Nominal size,

c) Pressure rating,

d) Direction of flow, and

e) Tag number.

5.1.2 The control valves may also be marked with the ISI Certification Mark:

NOTE — The use of the ISI Certification Mark is governed by the provisions of the Indian Standards Institution (Certification Marks) Act and the Rules and Regulations made thereunder. The ISI Mark on products covered by an Indian Standard conveys the assurance that they have been produced to comply with the requirements of that standard under a well-defined system of inspection, testing and quality control which is devised and supervised by ISI and operated by the producer. ISI marked products are also continuously checked by ISI for conformity to that standard as a further safeguard. Details of conditions under which a licence for the use of the ISI Certification Mark may be granted to manufacturers or processors, may be obtained from the Indian Standards Institution.

6. TESTS

6.0 General

6.0.1 *Flow Testing with Incompressible Fluids*

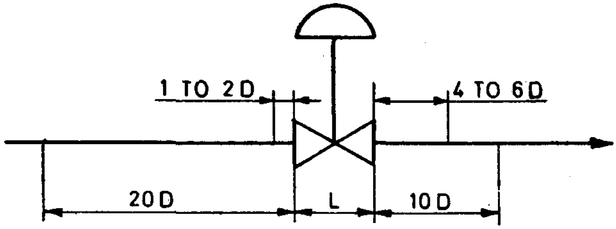
6.0.1.1 *Standard test section* — The standard test section shall consist of two straight lengths of pipe having a minimum length of 20 nominal pipe diameters (20 D) upstream and 10 nominal pipe diameters (10 D) downstream (*see* Fig. 3).

These pipes shall be connected to the control valve to be tested with suitable means. The pipes shall be of the same nominal size as the

nominal size of the control valve. The pipe shall be free from scale, rust or other obstructions which may cause excessive flow disturbance.

NOTE 1 — It should be noted that misalignment of the pipe against the control valve or the use of pipe which differs in inside diameter from the body ends of the valve may result in variations of the flow coefficient obtained.

NOTE 2 — Straightening vanes may be used where beneficial. If employed, the length of the upstream test section may be reduced to 10 nominal pipe diameters.



D = Nominal Pipe Diameter

FIG. 3 STANDARD TEST SECTION

6.0.1.2 *Pressure taps* — Pressure taps shall be located at distances between one nominal pipe diameter (1 D) and two nominal pipe diameters (2 D) upstream and between four nominal pipe diameters (4 D) and six nominal pipe diameters (6 D) downstream of the control valve. All pressure taps shall be horizontal to reduce the possibility of air entrapment and collection of dirt. The centreline of the pressure tap shall meet the centreline of the pipe and be at right angle to it. At the point of break-through, the hole shall be circular, and the edges shall be flush with the pipe wall, sharp and free from burrs. The inside diameter of the pressure taps shall be not more than one-tenth nominal diameter (0·1 D) of the pipe or 12 mm, whichever is less, and shall be not less than 3 mm. The upstream and downstream pressure taps shall be of the same diameter.

6.0.1.3 *Measurement errors* — The methods of measuring the following parameters shall be such that the error shall not exceed the limits given below:

a) Differential pressure : ± 2 percent of the actual differential pressure

b) Flow rate : ± 2 percent of the actual flow rate;

c) Temperature : ± 2°C; and

d) Valve travel : ± 1 percent of rated travel.

6.1 Classification of Tests

6.1.1 *Type Tests* — The following shall constitute type tests:

a) Visual examination (*see* **6.2**),

b) Dimensional check (*see* **6.3**),

c) Hydraulic pressure test (*see* **6.4**),

d) Gland leakage test (*see* **6.5**),

e) Seat leakage test (*see* **6.6**),

f) Determination of flow coefficient (*see* **6.7**), and

g) Determination of inherent flow characteristic (*see* **6.8**).

6.1.2 *Routine Tests* — The following shall constitute routine tests:

a) Visual examination (*see* **6.2**),

b) Dimensional check (*see* **6.3**),

c) Hydraulic pressure test (*see* **6.4**),

d) Gland leakage list (*see* **6.5**), and

e) Seat leakage test (*see* **6.6**).

6.2 Visual Examination — The control valve shall be visually examined for assembly, workmanship and finish and shall be free from injurious flaws, cracks and blow holes.

6.3 Dimensional Check — The dimensions shall be checked with measuring instruments having least count of 0·1 mm. The dimensions shall conform to that specified by the manufacturer.

6.4 Hydraulic Pressure Test — A control valve without painting shall be used for the test. The test shall be conducted with water at ambient temperature and at a pressure of 1·5 times the rating of the valve, applied for 30 minutes. At intervals of 5 minutes the valve shall be tapped with a soft hammer. There shall be no leakage or wetting of the surface of the control valve.

6.5 Gland Leakage Test — The test shall be conducted as specified in **6.4**. During the test there shall be no leakage at the gland packing of the control valve.

6.6 Seat Leakage Test – The seat leakage rate of a control valve shall be determined using air or water at a temperature between 3°C and 40°C

at a differential pressure between 200 kPa (2 bar) and 400 kPa (4 bar) at the normal valve inlet and exhausting to atmosphere.

The actual test pressure and medium used for this test shall be specified. The duration of the test shall be sufficient to establish a constant seat leakage rate. A lower test pressure shall be used where the maximum working differential pressure is less than 200 kPa (2 bar). In such cases, the test pressure shall be limited to the maximum working differential pressure.

On tests done with water, care shall be taken to eliminate air pockets in the valve body and piping.

NOTE — Seat leakage tests are carried out in order to ensure that a uniform acceptance standard for manufacturing quality is maintained. It is not recommended that the results be used to establish expected seat leakage rates under actual working conditions.

6.6.1 *Low Seat Leakage Rates* — Control valves used for service conditions requiring exceptionally low seat leakage rates may be subjected to a seat leakage test with water at the maximum control valve working pressure and at a temperature between 5°C and 40°C.

Under these conditions, the seat leakage rate in the normal flow direction with atmospheric discharge and with a specified actuator force shall comply with the following requirement:

$$Q_1 \leqslant 5 \times 10^{-14} d_0 \triangle P$$

where

Q_1 = seat leakage rate in cubic metres per second,

d_0 = control valve port diametre in metres, and

$\triangle P$ = pressure differential across the control valve in pascals.

Alternatively, the following may be used:

$$Q_1 \leqslant 5 \times 10^{-6} d_0 \triangle P$$

where

Q_1 = seat leakage rate in cubic centimetres per second,

d_0 = control valve port diameter in millimetres, and

$\triangle P$ = pressure difference across the control valve in bar.

6.6.2 In the case of bubble tight shut off valves for gas service, leakage test shall be conducted with air at a pressure of 700 kPa. A disc with a

central pin hole shall be fixed to the outlet end of the control valve and soap solution applied to it. The bubble at the central pinhole shall not break within 30 seconds.

6.7 Determination of Flow Coefficient — The test shall be carried out with water flowing steadily at a temperature between 5°C and 40°C. The travel shall be set at the value for which the flow coefficient is required to be found. The pressure differential shall be set to a convenient value not less than 35 kPa (0·35 bar) and not more than 69 kPa (0·69 bar). Ensuring that the test line is full of water during the test, the flow rate shall then be measured. The value of the flow coefficient shall be calculated using the equations given in **2.3** and using the measured values of pressure differential and flow rate. The pressure differential shall then be increased in two successive steps of at least 20 kPa (0·2 bar) each.

For each value of the pressure differential, the measurement of flow rate shall be repeated, and a value of the flow coefficient shall be obtained. The three values so obtained shall be such that the largest value is not more than 4 percent greater than the smallest value. The arithmetic mean of the three values shall be calculated to provide a single value of the flow coefficient corresponding to the specific value of relative travel used.

NOTE — If vaporization or cavitation occurs inside the control valve, it could cause a large difference between the values obtained for the flow coefficient. Therefore, if the difference exceeds the tolerance specified, the test shall be repeated using a higher inlet pressure to eliminate this effect.

6.8 Determination of Inherent Flow Characteristic — The travel of the control valve shall be set in turn to positions for which the relative travel has the values:

0·05 — 0·1 — 0·2 — 0·3 — 0·4 — 0·5 — 0·6 — 0·7 — 0·8 — 0·9 — 1·0

then:

1·0 — 0·9 — 0·8 — 0·7 — 0·6 — 0·5 — 0·4 — 0·3 — 0·2 — 0·1 — 0·05

For each value of the relative travel the flow coefficient shall be found in the manner specified in **6.7**. Using these values, a graph of relative flow coefficient ϕ against relative travel h shall be plotted to give the inherent flow characteristic.

6.8.1 The following data shall be recorded:

a) The classification, nominal size and pressure rating of each control valve tested;

b) The direction of flow, water temperature and inlet pressure during each test;

c) The flow rate, pressure differential and travel for each individual determination; and

d) The values of flow coefficients determined using the above data.

APPENDIX A

(*Clause* 2.3)

BASIS FOR DETERMINING FLOW COEFFICIENT

A-1. A control valve, when installed in a pipeline, causes a resistance to the flow of liquid and produces an irrecoverable pressure loss.

It can be shown experimentally that, under conditions of turbulent flow, this pressure loss is directly proportional to the velocity head. For all values of the pressure loss below that value at which some vaporization occurs in the flow stream:

$$\Delta \rho = \Sigma \rho \frac{v^2}{2}$$

where

ΔP = pressure loss,

Σ = non-dimensional pressure loss coefficient,

ρ = density of liquid, and

v = mean velocity of the liquid.

But because

$$Q = vA, \text{ thus } v^2 = \frac{Q^2}{A^2}$$

where

Q = volumetric flow rate, and

A = cross-sectional area.

It then follows that

$$Q = A\sqrt{\frac{2}{\Sigma}} \quad \sqrt{\frac{\Delta P}{\rho}}$$

The expression $A \frac{2}{\Sigma}$ can be replaced by a simple coefficient A_V which (since Σ is non-dimensional) will have the dimension of area and will express the relationship between pressure loss and flow rate through the control valve.